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AUTHOR	Lee, Sunny S. U.; Fraser, Barry J.
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ABSTRACT

The purpose of this study was to investigate Korean high school students' perceptions of their laboratory classrooms, focusing especially on the aspects measured by the items in the Science Laboratory Environment Inventory (SLEI). The study involved 439 high school students from three different streams (145 from the humanities stream, 195 from the science-oriented stream, and 99 from the science-independent stream). The validity and reliability of a translated version of the SLEI were confirmed when used with Korean students. Associations between laboratory classroom environments and students' attitudes were found. When the perceptions of students from the three streams were compared, it was found that students from the science-independent stream perceived their classroom environments more favorably than did students in the other two streams. Interviews with students confirmed their responses to items in the SLEI and provided additional information about laboratory classroom environments in Korea. (Contains 39 references, 5 tables, and 2 figures.) (Author/MM)

Laboratory Classroom Environments in Korean High Schools

Sunny S .U. Lee & Barry J. Fraser
Science & Mathematics Education Centre
Curtin University of Technology
Perth, Australia

Abstract
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The purpose of this study was to investigate Korean high school students' perceptions of their laboratory classrooms, focusing especially on the aspects measured by the items in the Science Laboratory Environment Inventory (SLEI). The study involved 439 high school students from three different streams (145 from the humanities stream, 195 from the science-oriented stream and 99 from the science-independent stream). The validity and reliability of a translated version of the SLEI were confirmed when used with Korean students. Associations between laboratory classroom environments and students' attitudes were found. When the perceptions of students from the three streams were compared, it was found that students from the science-independent stream perceived their classroom environments more favourably than did students in the other two streams. Interviews with students confirmed their responses to items in the SLEI and provided additional information about laboratory classroom environments in Korea.

Key words: laboratory classes, learning environment, differences between streams, high schools, students' attitudes

Introduction

There has been continuous concern about school science laboratories (particularly, in primary and junior high schools) among educators in Korea (Choi & Nam, 1995; Kim & Kim, 1995, 1996; Kim & Lee, 1997; Noh & Choi, 1996). They reported that laboratory activities are not conducted effectively in schools, which is inconsistent with the recommendations from curricula. It was also pointed that the situation in senior high schools were worst, which meant that laboratory lessons were least likely to be conducted at this level. They also found that science teachers normally experience a clash between their ideal image about science lessons and the real situation in their own science lessons. According to those teachers, they accept the fact that understanding of basic concepts and applying them in explaining natural phenomena are the most important objectives in science education. However, almost all teachers run laboratory lessons involving students' experiments only once or twice in a semester. More than half of the teachers reasoned that this was due to the pressure of the entrance examination system for colleges and universities, heavy teaching loads, or the lack of time for laboratory activities.

This study aimed to obtain a more comprehensive picture of laboratories within schools, particularly in senior high schools, by focusing on students' perceptions about their own laboratories. The fact that Korean senior high schools have three different science streams, each with its own unique science curriculum, was a main focus in this study. In other words, because of the different science curricula depending on stream, each stream has its own laboratory classroom environment. The frequency and quality of laboratory activities also depend on stream. Humanities stream students have less chance to experience laboratory classes than do the students in the other two streams. Science-oriented stream students are expected to get more chances to be in laboratory classes, and science-independent stream students are supposed to get many more chances to experience laboratory classes with better facilities, compared to the other two streams.

Since the Science Laboratory Environment Inventory (SLEI) was developed by Fraser, Giddings and

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McRobbie (1992, 1993, 1995) with an awareness of the importance of laboratory lessons in science learning, aspects of laboratory classroom environments have been widely investigated in various settings. Initially, the SLEI was developed by involving Australian secondary school students (Fraser, 1991) and was extensively validated in diverse settings such as the US, Australia, Canada, England, Israel, Nigeria, Brunei, Singapore and countries in South Pacific Islands (Fraser, Giddings & McRobbie, 1995; Giddings & Waldrip, 1996; Wong & Fraser, 1996). It is noteworthy that the development of the SLEI involved the creation of a new format for learning environment instruments, which was based on the realisation that a student can have his/her own perceptions about the classroom which can vary for different students in the same class. As a result, a *Personal* form of the SLEI was developed and later applied to other instruments such as What Is Happening In this Class (WIHIC; Aldridge & Fraser, 1999) in learning environment research. Along this line of research effort, this study was aimed to investigate Korean high school students' perceptions of their laboratory classrooms, focusing on the aspects measured by the items in the SLEI.

Past research

General insight of learning environment research

The research on learning environment in classrooms and school systems has been conceptualised, established as a significant research field and continuously flourished in various contexts (e.g. different school levels, different cultural settings and different subject areas etc; Fraser, 1998). The unique development of the field of learning environment research is closely associated with the availability of various measurement tools since very early stage. Based on this advantage (easy access to stake-holders such as researchers, teachers and other educators), the studies in the field of learning environment research have contributed to provide useful insights for educators, including science teachers.

Although several landmark studies were carried out in western countries such as Australia and the Netherlands, the contribution from Asian countries needs to be highlighted as crucial stage of development of this field of research. This contribution is also applicable to the development of the SLEI and its usage.

The Development of the SLEI and its Use in Asian Countries

The development of the SLEI was initiated with an awareness of the importance of laboratory lessons in science education (Fraser, McRobbie & Giddings, 1993). The initial version of the SLEI contained eight scales, with nine items in each scale. The preliminary version of SLEI was field tested in six countries, namely, Australia, Canada, England, Israel, Nigeria and USA. It was refined later based on item and factor analyses, ending up with 35 items in the five scales of Student Cohesiveness, Open Endedness, Integration, Rule Clarity and Material Environment (with seven items in each scale).

The SLEI first was developed in a Class form, which assesses a student's perceptions of the class as a whole (Fraser, McRobbie & Giddings, 1993). Despite success in using the *Class* form of classroom environment instruments in past learning environment research, several studies mentioned a potential problem in using this form (Fraser & Tobin, 1991; Tobin, Kahle & Fraser, 1990). The *Class* form only elicits a student's perceptions of the class as a whole, and not his/her perceptions of his/her role within the class. In response to this concern, Fraser, Giddings and McRobbie (1995) constructed a *Personal* form of the instrument by rewording corresponding items in the *Class* form of the SLEI. The main advantage of this *Personal* form is that it is more sensitive for studying subenvironments within classes (eg. target students and gender subgroups) and in case studies of individual students. For example, an item "Students are able to depend on each other for help during laboratory classes" in the Class form is reworded as "I am able to depend on other students for help during laboratory classes" in the Personal Form. The Personal form of the SLEI comes in separate actual and preferred versions like the Class form.

The actual and the preferred versions of a Personal form of the SLEI were validated by comprehensive studies in a broad range of contexts, including (developing countries, developed countries, senior high schools, and the university level. (Fisher, Henderson & Fraser, 1997; Fraser & McRobbie, 1995; Fraser & Wilkinson, 1993; Waldrip & Wong, 1996; Wong & Fraser, 1996). The development of a *Personal* form of the SLEI initiated the use of this form in the field of learning environment research.

The SLEI has been used in various contexts, including non-English speaking countries and English-speaking countries. Giddings and Waldrip (1996) found surprisingly similar science laboratory learning environments across most high schools throughout researched countries, with one of the environment scales, Open-Endedness, having the least favourable score. According to a study conducted by Giddings and Waldrip (1996), Australian and USA teachers tend to perceive more favourably the scales of Student Cohesiveness and Open-Endedness than did Asian and South Pacific teachers and students. These findings seem to suggest that science teachers are largely unconvicted as to the value of open-ended practical activities in science laboratory classrooms (Giddings & Waldrip, 1996).

Wong and Fraser (1996) investigated Singaporean secondary chemistry students' and teachers' perceptions of their laboratory lessons. They investigated differences in perceptions of actual and preferred chemistry laboratory environments between teachers and students, students of different streams, and male and female students. They examined associations between classroom environment and students' attitudes towards chemistry. They reported that (1) perceptions of students and teachers differed, (2) students wanted to experience more positive laboratory lessons than those presently provided, (3) students from different streams differed only in their preferred perceptions, (4) females held more favourable perceptions than males, and (5) positive associations existed between the nature of the chemistry laboratory environment and students' attitudinal outcomes.

Using the SLEI, associations with students' cognitive and affective outcomes were found for a sample of 489 senior high school biology students in Australia (Henderson, Fisher & Fraser, 2000) and 1592 grade 10 chemistry students in Singapore (Wong & Fraser, 1996). The examples of research dealing with the SLEI can also be found in Asian countries (Margianti & Fraser, 2001; Riah & Fraser, 1998). Among those studies conducted in Asia, Riah and Fraser (1998) explored the environmental perceptions of chemistry theory classrooms and laboratory classrooms in Brunei secondary schools by using the adapted questionnaires including the SLEI.

Korea Studies with the SLEI

In Korea, since Yoon's (1993) pioneering study on the psychosocial environment in science laboratory classes, science classroom environment in Korea has been investigated by several researchers (Kim, Fisher & Fraser, 1999; Kim & Kim, 1995, 1996; Kim & Lee, 1997; Noh & Choi, 1996). Among them, Kim and Kim (1995, 1996) especially have completed sustained research on laboratory classroom environments, which were investigated for various levels of learners and teachers. Her concern was extended to investigating the effect of curriculum reform, which can be characterised by constructivist approaches, which have been formally reflected in the science curriculum since 1982. She also suggested that more qualitative research methods are needed to completely explain the quantitative results and to understand the real socio-psychological environments of science classrooms in detail so that they can be improved in Korea. The present study was initiated with her pioneering guidance for the direction of future research in Korea.

Design and procedures

In order to get a current picture of Korean science laboratory classroom environments, three different methodologies (survey, interview and observation) were employed. Survey has been extensively used in the field of learning environments to take advantage of perceptual measurement for relatively large samples. Interview and observation have been used mainly in studies which try to achieve a more comprehensive understanding, based on the notion of 'combined approaches' (Fraser, 1998). Because these two approaches sometimes are presumed to be incompatible within the dualistic point of view (Denzin & Lincoln, 1998; Howe, 1988), this combination could be difficult to explain. This dilemma was resolved by replacing the dualistic notion with a rather practical notion for the present study. Because we did not want to lean on a specific paradigm, we focused on the main question of "what have we tried to find out with the people involved in this particular study?" (adapted from Punch, 1998). The procedures involved in the present study are described in following three sections.

Survey

As the initial step, a survey was conducted by administering a questionnaire (SLEI) to students in three streams. The questionnaire was prepared using procedures such as translation, back-translation and confirmation of interpretive validity of the translated version, as recommended by Brislin (1976) and Newmark (1988). Initially, the first author translated the English version into Korean. In the translation, each item was either *translated literally* or *translated with meaning,* as suggested by Newmark (1988). As the final step of translation, two English-speaking academics checked the back translations to make sure that the Korean questionnaires conveyed the same meaning as the English questionnaires. This translation process confirmed only the literal meaning transfer. After the translation process and subsequent pilot testing, instruments were administered to students. A pilot study involving each of the questionnaires was conducted to ensure that the translation of the questionnaires was appropriate and that students were interpreting items in the way in which they were intended. For some items, this necessitated the modification of the original English version, the Korean translation, or both. Insights from the pilot study guided revisions of the questionnaires for the main study. The students' responses to the questionnaire were stored and analysed with the SPSS program.

The original version of SLEI has 35 items in 5 different scales (Student Cohesiveness, Open-Endedness, Integration, Rule Clarity and Material Environment), containing 7 items in each scale. The five response alternatives for each item are Never, Almost Never, Sometimes, Almost Always and Always. This 35-item version was translated into Korean and administered to the students involved in the present study. Instead of maintaining the 35-item version as originally designed, a modified 23-item version of the SLEI, with 4 or 5 items in each of the five scales (5 items in Student Cohesiveness, 4 items in Open-Endedness, 5 items in Integration, 5 items in Rule Clarity, 4 items in Material Environment) was decided upon as the optimal structure for the final Korean version of the questionnaire. Details about validation procedures are described in results section below.

In addition to the main questionnaires SLEI, the TOSRA (Test Of Science-Related Attitude) was also used after following similar procedure as described for SLEI (translation and back-translation). This attitude questionnaire was selected to use with the aim of investigating any possible relationships with students' perceptions about their laboratory environment.
Whereas the initial version of TOSRA (developed by Fraser, 1978) consists of seven scales - Social Implication of Science, Normality of Scientists, Attitude toward Scientific Inquiry, Career Interest in Science, Leisure Interest in Science, Enjoyment of Science Lessons and Adoption of Scientific Attitude - , the present study employed only four scales through statistical procedures (factor analysis followed by renaming the scales) such as Social Implications of Science, Normality of Scientists, Attitude to Scientific Inquiry , Interest in Science.

Interview

For this study, 439 students in 13 classes (4 classes from the humanities stream, 4 classes from the science-oriented stream and 5 classes from the science-independent stream) were selected from three schools. Two or three students from each class were selected for face-to-face interview in the humanities stream and the science-oriented stream. In the case of students in the science-oriented stream, interviews were conducted via e-mail to overcome practical constraints. All of the face-to-face interviews were audio-taped and later transcribed in Korean and translated into English. When the Korean transcriptions were completed, they were shown to the students to obtain comments and feedback from them, in order to make sure that their voices had been clearly understood.

Observation

One class from each stream was selected for observation. While the researcher was observing, she wrote down any salient events occurring in the classroom whenever possible. Some photographs were also taken. The field notes made and also translated into English in order to transfer the images into English. The results from these three methods are described below.

Results

Validation of SLEI

The initial stage in the cross-validation of the Korean-language version of the SLEI involved a factor analysis of its original 35-items for the Korean sample, using the principal components method (with varimax rotation) with the individual student as the unit of analysis. Through an iterative process involving deleting inappropriate items, a 23-item version of the SLEI, with 4 or 5 items in each of the five scales (5 items in Student Cohesiveness, 4 items in Open-Endedness, 5 items in Integration, 5 items in Rule Clarity, 4 items in Material Environment) was decided upon as the optimal structure for the final version of the questionnaire. The results of the final factor analysis are shown in Table 1, with all factor loadings smaller than .4 omitted.

When the 35-item, Korean version of SLEI was factor analysed, some items loaded heavily on more than one factor, and several other items had factor loadings on their own scale with negative or low positive values. Therefore, 10 of the original items, namely, Items 6, 26, 22, 27, 13, 18, 28, 9, 24 and 10, were deleted before a second series of analyses was undertaken. During the second and third stages of analysis, further items were deleted because they loaded heavily on more than one factor. In the final analysis, the 5-factor structure appeared as intended in the original instrument. In the overall process, the 23 items shown in Table 1 survived out of original 35 items in the instrument.

Table 1. Factor Loadings for Items in the SLEI

	Factor Loading				
Item No.	Student Cohesiveness	Open-Endedness	Integration	Rule Clarity	Material Environment
11	.74				
1	.67				
31	.59				
21	.57				
16					
8		.75			
33		.72			
3		.71			
23		.66			
34			.78		
14			.62		
4			.59		
19			.55		
29			.51		
17				.69	
32				.65	
7				.60	
12				.55	
2	.41			.50	
25					.66
5					.63
20					.62
15					.61
% variance	10.99	10.43	9.94	9.40	9.05
Eigenvalue	2.53	2.40	2.29	2.16	2.08

Loadings smaller than .4 omitted. The sample consisted 439 students in 13 classes.

The results of the final factor analysis are represented in Table 1, which shows that there is only one case (Item 2) out of 115 cases (23 items x 5 scales = 115 items) for which an item either has a factor loading smaller than .4 with its own scale or has a loading of .4 or greater on any of the other four scales. For this final factor structure, 50% of the variance could be accounted for by five interpretable factors, namely, Student Cohesiveness, Open-Endedness, Integration, Rule Clarity, and Material Environment.

Item analyses for the remaining 23 items of the SLEI showed that the alpha reliability coefficient for different scales ranged from .62 to .72 when using individual student as the unit of analysis, and from .58 to .97 when using class mean as the unit of analysis (Table 2). The discriminant validity (mean correlation of a scale with other scales) ranged from .16 to .34 when using the individual students as the unit of analysis, and from .19 to .46 when using class as the unit of analysis. These findings suggest that each scale was reliable and measures a unique dimension of the laboratory classroom environment. Although there is some overlap in raw scores on SLEI scales, the factor analysis results attest to the independence of factor scores.

A one-way analysis of variance (ANOVA) was also performed for each SLEI scale, in order to assess each scale's ability to differentiate between the perceptions of students in different classrooms. The last column in Table 2 reports the result of the analyses in terms of the eta^2 statistic (which is the ratio of between total sums of squares and represents the proportion of variance in scale scores accounted for class by membership). The values of the eta^2 were statistically significant (p<.01) and ranged from .03 to .08 for different scales, suggesting that each scale of the SLEI was able to differentiate between the perceptions of students in different classes.

Table 2 Internal Consistency Reliability (Cronbach Alpha Coefficient), Discriminant Validity (Mean Correlation With Other Scales) and Ability to Differentiate Between Classrooms (ANOVA Results) for Two Units of Analysis for SLEI scales

Scale	Alpha Reliability		Discriminant Validity		ANOVA Eta^2
	Ind	Class	Ind	Class	
Student Cohesiveness	.70	.91	.34	.46	.08**
Open-Endedness	.64	.58	.18	.44	.07**
Integration	.72	.97	.23	.44	.08**
Rule Clarity	.67	.91	.16	.19	.03
Material Environment	.62	.78	.17	.31	.04**

*$p<0.05$
**$p<0.01$

Describing Korean high school science laboratory environments

In this section, science laboratory environments are described for Korean high schools, based on students' responses to the questionnaire. Table 3 shows the average item mean (obtained by dividing the scale mean by the number of items in that scale) for each scale in the SLEI for the total sample of 439 students. Figure 1 provides a graphical representation of the mean scores for each scale.

Table 3 Average Item Mean and Average Item Standard Deviation for SLEI Scales

Scale	No of Items	Unit of Analysis	Average Item Mean	Average Item Standard Deviation
Student Cohesiveness	5	Ind	3.73	.39
		Class	3.71	.37
Open-Endedness	5	Ind	2.58	.75
		Class	2.61	.13
Integration	4	Ind	3.94	.79
		Class	3.89	.27
Rule Clarity	5	Ind	3.65	.74
		Class	3.57	.25
Material Environment	4	Ind	3.21	.89
		Class	3.16	.22

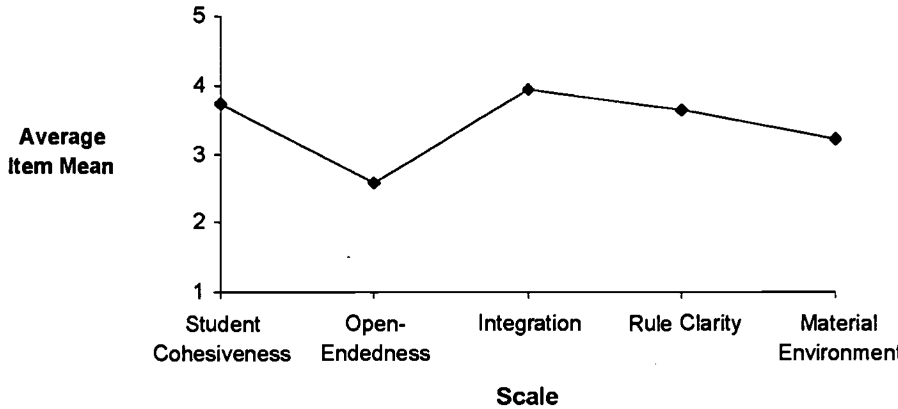

Figure 1. Korean High School Students' Average Perceptions on the Science Laboratory Environment Inventory

Overall, students perceived that their science laboratory lessons are relatively favourable, as implied by the range of 2.6 to 3.9 (meaning that students perceived the events as described by the questionnaire with a frequency range from 'sometimes' to 'often') for the average item mean for different SLEI scales in Figure 1. The mean score for the Student Cohesiveness scale implies that students perceive a relatively high level of cohesiveness in their laboratory lessons. For the Integration scale, the mean is the highest of all scales (near to 4.0 which corresponds to 'often'), implying that laboratory classes are highly coordinated with theory classes. This is likely to be the case because laboratory classes are usually run with the aim of encouraging students to check what they have already learned in theory classes. Also the laboratory lessons are normally carried out using 'ready-made' procedures and results, as suggested by the fact that the lowest mean score occurred for the Open-Endedness scale (mean intermediate between 'seldom' and 'sometimes'). These two scale means (for Integration and Open-Endedness) reflect the most common nature of science laboratory lessons in Korea, which are run using rigid procedures based on the theory classes.

The rules in laboratory classes are also relatively clear, usually coming from the theory classes as well (see the Rule Clarity mean of between 3 and 4 in Figure 1). Disappointingly, the material and equipment were perceived to be inadequate, with the second lowest mean score of around 3 (corresponding to 'sometimes') occurring for the Material Environment scale.
These results from the survey were further explored with interview and observation data. Using those two qualitative modes of inquiry, stream differences in laboratory lessons were explained and the general picture of laboratory environments was clarified.

The low level of Open-Endedness in the laboratory classroom environment in this study was also reported in previous studies in various countries (Fraser & McRobbie, 1995; Waldrip & Wong, 1996; Wong & Fraser, 1995). Students' responses to the Integration scale are consistent with the science teachers' attitudes in Korea reported by Swain, Monk and Johnson (1999), who found that Korean science teachers have a positivistic attitude to science and that science practical work emphases factual recall and illustrative practicals. Swain et al. also found that Korean science teachers understand that laboratory tasks normally reinforce what students already learn in theory lessons. They acknowledge that practical work should be aimed at enhancing creativity but, in actual fact, they seldom focus on creativity, which can be explained by the examination-driven nature of science education in Korea, particularly at the senior high school level.

Stream differences in laboratory learning environments

The differences between the perceptions of students in three different streams were also sought as one of the main aims in this study. In order to investigate stream differences in laboratory environments, a one-way MANOVA was conducted with data for the set of SLEI scales for the sample of 439 students (145 from the humanities stream, 195 from the science-oriented stream and 99 from the science-independent stream).. Because the multivariate test using Wilks' Lambda criterion was statistically significant, one-way ANOVA was performed separately for each SLEI scale. Because the number of streams for comparison was three, a post hoc test was computed to identify significant difference between each pair of streams (humanities and science-oriented, science-oriented and science-independent, humanities and science-independent). The results are described in tabulated form in Table 4 and in graphical format in Figure 2.

Table 4 ANOVA Results for Stream Differences for SLEI

Scale	F	Significant t Values		
		Streams1& 2	Streams 2 & 3	Streams 3 & 1
Student Cohesiveness	10.28**		-5.43**	-7.45**
Open-endedness	4.59**		-8.01*	-4.07**
Integrity	1.27			
Rule Clarity	17.93**		-3.13**	-9.53**
Material Environment	33.43**		-1.70**	-10.85**

*p<.05
**p<.01

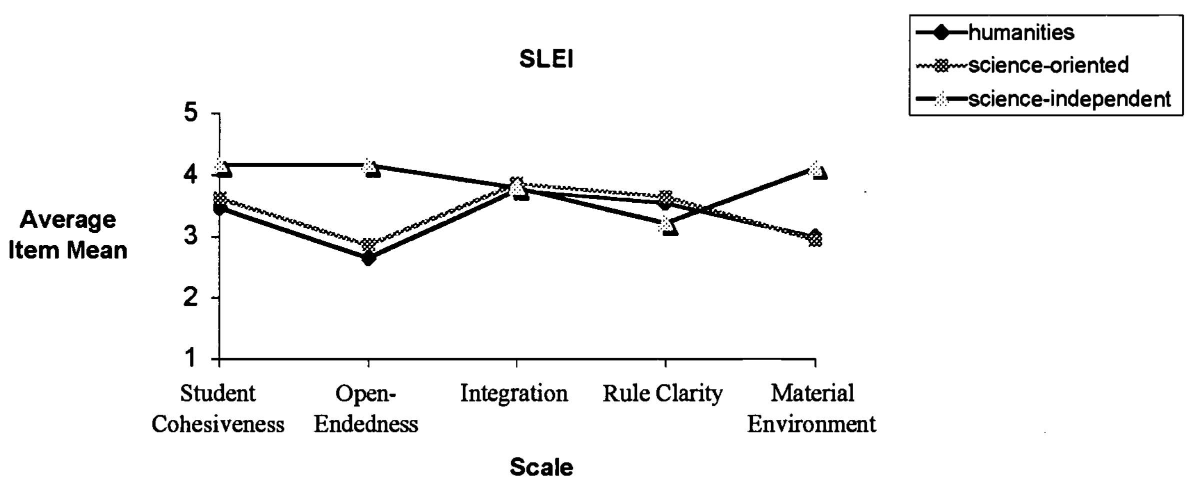

Figure 2 Differences Between Three Streams in Students' Average Item Means on the SLEI

Firstly, the ANOVA results in Table 4 show that the Integration scale was perceived almost similarly across streams. The results for the other four scales indicate that each stream has its unique environmental features, which are reflected in subtle and critical differences between streams. The result of the t tests reflect that students from the humanities stream and the science-oriented stream perceive their classes similarly, but that their perceptions are significantly different from those of the humanities stream. Science-independent stream students perceive more cohesiveness between themselves in their laboratory sessions and they also perceived their laboratory lessons as much more open-ended than do students in the other two streams. The rules in laboratory classrooms are perceived by science-independent stream students to be less clear than by students from the other two streams. Material environment is perceived more positively in the science-independent stream than in the other two streams. It is noteworthy that science-independent stream students perceive more open-ended laboratory lessons, with less clear rules and better materials, than do students in the other two streams.

Associations between Perceptions of Laboratory Classroom Environments and Attitudes Towards Science

Another aim of this study was to identify the types of science laboratory classroom environments that promote students' positive attitudes to science. In order to achieve this aim, two types of analysis were undertaken using the data provided by the SLEI and TOSRA for the sample of 439 students in 13 classes.

Firstly, a simple correlation was calculated in order to ascertain the extent to which each scale in the SLEI is associated with each individual attitudinal scale in TOSRA. Secondly, a multiple regression analysis was conducted for each attitude scale to provide the information about the joint influence of correlated SLEI scales on attitudes.

Simple correlations (Table 5) based on the individual as the unit of analysis indicate that there was a statistically significant (p<.01) correlations between each of the four TOSRA scales and the SLEI scales of Student Cohesiveness, Integration and Rule Clarity. For the two TOSRA scales of Social Implications of Science and Attitude to Scientific Inquiry, there were statistically significant (p<.01) correlations with Open-Endedness. For the two TOSRA scales of Normality of Scientists and Interest in Science, there were statistically significant (p<.01) correlations with Material Environment. Compared with the case of using class as the unit of analysis, in which only two simple correlations out of total 20 possible cases showed statistical significance (p<.05), many more cases (16 out of 20) were associated with statistically significant associations between environmental perceptions and attitudinal outcomes when the individual was used as the unit of analysis.

Table 5 Simple Correlation and Multiple Regression Analyses for Associations between Student Attitudes and SLEI for Two Units of Analysis

SLEI Scale	Unit of analysis	Attitude-Environment Association							
		Social Implications of Science		Normality of Scientists		Attitude to Scientific Inquiry		Interest in Science	
		r	β	r	β	r	β	r	β
Student Cohesiveness	Ind	.30**	.20**	20**	.09	.27**	.12*	.23**	.04
	Class	.70*	.93	-.23	.31	.49	.98	.09	.69
Open-Endedness	Ind	.20**	11**	.00	-.09	.11**	.08	.06	.02
	Class	.48	-.58	-.59	-1.98*	.18	-.97	-.22	-1.86
Integration	Ind	.33**	.20**	.14**	.10*	.24**	.13**	.20**	.12**
	Class	.61	.29	-.16	1.14	.35	.19	.18	.92
Rule Clarity	Ind	.15**	.04	20**	.12**	.27**	22**	.33**	.29**
	Class	.00	-.26	.20	-.08	.21	-.20	.10	-.28
Material Environment	Ind	.06	-.03	14**	13**	.01	-.07	.09*	.03
	Class	.21	.12	-.08	.29	.22	.40	.16	.47
Multiple Correlation, R	Ind		.40**		.27*		.36**		.36**
	Class		.76		.93		.64		.82

* $p<.05$
** $p<.01$

As anticipated, due to the small number of classes in this study, significant results for the multiple correlation were found only with the individual as the unit of analysis (Table 5). Therefore, the following descriptions are based on the results when the individual is used as the analytical unit. R values in Table 5 indicate that statistically significant ($p<.01$) multiple correlations were found between each scale in the TOSRA and the set of all scales in the SLEI. The multiple correlation was greatest for Social Implications of Science.

In order to identify which SLEI scales contribute to each significant multiple correlation, the standardised regression coefficients (β) were examined. Values of β in Table 5 indicate that Integration is a significant independent predictor of all four attitudinal scales. Student Cohesiveness is a significant independent predictor of Social Implications of Science and Normality of Scientists scales. The Open-Endedness scale is a significant independent predictor of Social Implications of Science. Rule-Clarity is a significant independent predictor of all attitudinal scales, except Social Implications of Science. Material Environment is a significant independent predictor only of Normality of Scientists. These results indicate that students' attitudes to science are more likely to be positive in laboratory classes where students perceive greater Student Cohesiveness, Integration and Rule Clarity.

Overall, the results in Table 5 reflect relatively strong and consistent associations between the classroom environment and student attitudes when using SLEI and TOSRA with the individual as the unit of analysis. Almost all of the simple correlations were statistically significant ($p<.01$). It is noteworthy that that Integration scale uniquely accounted for a significant amount of variance in all of the attitudes scales represented in TOSRA. McRobbie and Fraser (1993) also reported that affective outcomes were superior in situations in which there is greater integration between the work covered in laboratory classes and theory classes.

Findings from Interviews with Students and Teachers

As described in the methodology section, interviews were conducted with students and teachers in order to obtain a more comprehensive picture of laboratory classroom environments in Korea. The information from interviews with students mainly contributed to clarifying their replies to the questionnaire. The interview with teachers also contributed to drawing conclusions by providing background information about the practical situation in classrooms and schools. Teachers in the science-independent school indicated that their schools run many more laboratory lessons than do normal academic stream schools. According to the curriculum, students in this stream are supposed to take scheduled laboratory lessons, which are allocated more often than for the other two streams. Students in the other two streams are also expected to take both theory lessons and laboratory classes. But, in the case of the humanities and science-oriented streams, laboratory lessons are not run, owing to the 'overloaded' content of theory lessons. During interview, students in science-independent stream said that they follow teachers' instructions and sometimes that they can take the initiative for laboratory activities.

In summary, the findings from interviews and observations regarding happenings in laboratory classes reflected the findings from survey with the SLEI. Generally, students in Korean high schools perceive that laboratory lessons are closely associated with theory lessons and that they have clear rules. The responses of students in interview reflected that students are expected to follow these rules in laboratory classes. It was also reported that experiments in laboratory lessons are normally organised with clear procedures, which lead to 'closed' experiments. Relatively strong cohesiveness among students in the laboratory lessons was found as another characteristics of Korean high schools. This is expected because students in Korean high schools spend their school time in the same class, called the 'homeroom', under the care of their homeroom teacher.

In addition to these general findings, some differences were also found among three streams. Compared to the students from the humanities and the science-oriented streams, students from the science-independent stream reported experiencing more frequent experiments with more abundant materials in their laboratory lessons. It is also noteworthy that students who are involved in extracurricular science activities irrespective of the stream have more opportunities to access laboratories.

Discussions and Conclusion

This study involved the translation, validation and us of a Korean-language version of the Science Laboratory Environment Inventory (SLEI) with a sample of 439 high school science students from three streams (humanities, science-oriented and science-independent). Overall, the results supported the *a priori* five-factor structure of the Korean version of the SLEI, with scales showing satisfactory internal consistency reliability and differentiating between the perceptions of students in different classrooms. Also, associations were found between student perceptions of their science laboratory classroom environments and several scales assessing students' attitudes to science. These patterns of results with Korean students replicate research with the SLEI in several other countries (Fisher, Henderson & Fraser, 1997; Fraser & McRobbie, 1993; Wong & Fraser, 1996).

As described in the results section, Korean high school students show similar answering patterns to those from other countries as reported in previous studies (Swain, 1999), when they are asked to reply to the Science Learning Environment Inventory (SLEI). Overall, Korean high school students show relatively favourable perceptions of their laboratory lessons, with the lowest score occurring for the Open-Endedness scale. It seems that laboratory lessons or practical activities related to science lessons are operated rather as supplementary to theory classes rather than being independently important in their own right. The lower score on Open-Endedness scale has been also reported in several previous studies in various countries (Giddings & Waldrip, 1996; Wong & Waldrip, 1996). Internationally, it is possible that science teachers are not convinced about the practical value of open-ended laboratory activities. This can be also applied to the Korean high school situation, where an examination-driven curriculum is normally prescribed and delivered. In other words, Korean science teachers usually do not place much value to laboratory activities, because laboratory lessons do not guarantee satisfactory student achievement.

A distinctive feature of this study is that it compared the science laboratory classroom environments of students in three different streams. Although students in the science-oriented stream held perpcetions that were similar to those of students in the humanities stream, students in the science-independent stream perceived a distinct and more positive science laboratory learning environment. In particular, science-independent stream students perceived more student cohesiveness and more open-ended laboratory activities than did students in the other two streams.

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Signature: Lee Seon uk	Printed Name/Position/Title: Sunny, LEE. Dr.	
Organization/Address: PO Box U 1987 Science & Mathematics Education Centre Curtin University of Technology Perth. Western Australia	Telephone: 618-9362-6615	FAX: 618-9266-3503
	E-Mail Address: coree11@yahoo.com	Date: 1/May/02